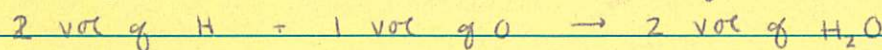
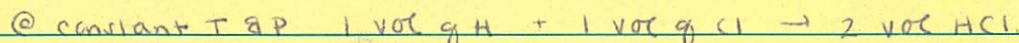
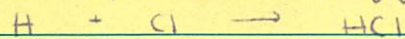


## Chapter 11: Molecular Composition of Gases

Gay Lussac - working with volumes of gases & rxns.

[biggerable  
diagrams say  
right now...]

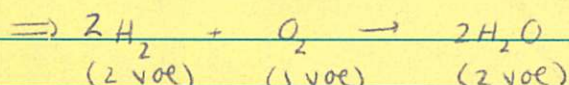
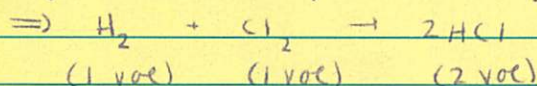


$\Rightarrow$  Gay Lussac's law of combining volumes: @ constant T & P the volume's of gas products & reactants can be expressed as ratios of small whole #'s.

Avogadro - worked w/ #'s of gas particles

$\Rightarrow$  Avogadro's Principle: at constant T & P, equal volumes of gases have equal #'s of particles.

$\rightarrow$  big dilemma... maybe diatomic?



Avogadro's principle: at a constant T & P, equal volumes of gases have equal #'s of particles.

ex. 3 L  $\text{H}_2 \rightarrow 1.5 \times 10^{22}$  molec  $\text{H}_2$ , at STP

3 L  $\text{O}_2 \Rightarrow$  # of moles of  $\text{O}_2 \rightarrow 1.5 \times 10^{22}$  molec  $\text{O}_2$

6 L He  $\Rightarrow$  # of moles of He  $\rightarrow 3.0 \times 10^{22}$  molec He.

★ • molar vol of a gas: @ STP, 1 mole = 22.4 L

EX: 7.02 L of  $\text{CH}_4$  = \_\_\_\_\_ mol  $\text{CH}_4$  @ STP

$$7.02 \text{ L CH}_4 \cdot \frac{1 \text{ mol CH}_4}{22.4 \text{ L CH}_4} = 0.313 \text{ mol CH}_4$$

EX: 7.02 L of  $\text{CH}_4$  = \_\_\_\_\_ mol  $\text{CH}_4$  @ 760 torr & 22.0°C

$\rightarrow$  use combined gas law:  $V_1 P_1 T_2 = V_2 P_2 T_1$  [want it in STP]

$\Rightarrow$  Charles' Law

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{(7.02 \text{ L})(273 \text{ K})}{(295 \text{ K})} = 6.4965 \text{ L}$$

$$6.4965 \text{ L CH}_4 \cdot \frac{1 \text{ mol CH}_4}{22.4 \text{ L CH}_4} = 0.290 \text{ mol CH}_4$$

Density of a Gas @ STP

• units:  $\frac{\text{g}}{\text{L}}$

- molar vol  $\rightarrow \frac{22.4 \text{ L}}{\text{mol}}$

- molar mass:  $\frac{\text{g}}{\text{mol}} = M$

$$D = \frac{M}{\text{molar vol.}} = \frac{\frac{\text{g}}{\text{mol}}}{\frac{\text{L}}{\text{mol}}} = \frac{\text{g}}{\text{L}}$$

EX: D of Ar @ STP  $\Rightarrow \frac{40 \frac{\text{g}}{\text{mol}}}{22.4 \frac{\text{L}}{\text{mol}}} = 1.78 \frac{\text{g}}{\text{L}}$

$\frac{M}{V}$



04-25-06

# Ideal Gas Law

- V vs. P (Boyle's Law)  $\Rightarrow V \propto \frac{1}{P}$
- V vs T (Charles' Law)  $\Rightarrow V \propto T$
- P vs T (Gay Lussac's Law)  $\Rightarrow P \propto T$
- n vs P  $\Rightarrow n \propto P$
- n vs V  $\Rightarrow n \propto V$

$$V \propto \frac{Tn}{P}$$

• all variables are proportionate by a constant.

takes into  
condition P, V, & T  
at non-standard  
P's or T's.

$$\Rightarrow V = \frac{n(R)T}{P}$$

• Ideal Gas constant  
(all other variables are  
connected by this variable!)

$$\Rightarrow \boxed{PV = nRT} \star$$

↳ Ideal Gas Law

$$\cdot R = \frac{PV}{nT}$$

$$\Rightarrow \frac{(1 \text{ atm})(22.4 \text{ L})}{(1 \text{ mol})(273 \text{ K})}$$

$$= 0.0821 \frac{\text{L atm}}{\text{mol K}}$$

→ must have these  
units!

04-26-06

EX: What volume will 16.2 g  $N_2$  occupy at 720 torr & 20.0 °C?

$$P \rightarrow 720 \text{ torr} \cdot \frac{1 \text{ atm}}{760 \text{ torr}} = 0.950 \text{ atm}$$

$$V \rightarrow ?$$

$$n \rightarrow 16.2 \text{ g } N_2 \cdot \frac{1 \text{ mol } N_2}{28 \text{ g } N_2} = 0.579 \text{ mol } N_2$$

$$R \rightarrow 0.0821 \frac{\text{L atm}}{\text{mol K}}$$

$$T \rightarrow 20.0^\circ \text{C} = 293 \text{ K}$$

$$\cdot V = \frac{nRT}{P} = \frac{(0.579 \text{ mol } N_2)(0.0821 \frac{\text{L atm}}{\text{mol K}})(293 \text{ K})}{(0.950 \text{ atm})} = \boxed{14.7 \text{ L}}$$

$$\cdot PV = nRT \Rightarrow PV = \frac{mRT}{M} \Rightarrow \boxed{M = \frac{mRT}{PV}} \star$$

n = moles  
m = mass  
M = molar  
mass

$$n = \frac{m}{M} = \frac{\text{g}}{\frac{\text{g}}{\text{mol}}} = \text{mol}$$

EX: m = 1.25 g

$$P = 750 \text{ torr} = 0.987 \text{ atm}$$

$$V = 350 \text{ mL} = 0.350 \text{ L}$$

$$T = 20.0^\circ \text{C} = 293 \text{ K}$$

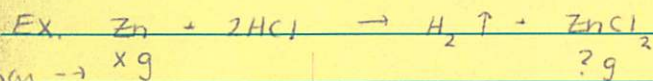
$$M = ?$$

$$\Rightarrow M = \frac{(1.25 \text{ g})(0.0821 \frac{\text{L atm}}{\text{mol K}})(293 \text{ K})}{(0.350 \text{ L})(0.987 \text{ atm})} = 87.0 \text{ g/mol}$$

$$\cdot D = \frac{m}{V} \Rightarrow M = \frac{DRT}{P} \Rightarrow \boxed{D = \frac{MP}{RT}} \star$$



04-27-06



• mass A  $\rightarrow$  mol A  $\rightarrow$  mol B  $\rightarrow$  mass B

If 25.0 g Zn reacts with an excess of HCl, what vol of  $\text{H}_2 \uparrow$  will be produced at STP? --> vol of B --> ideal gas law!

• mass A  $\rightarrow$  mol A  $\rightarrow$  mol B  $\xrightarrow{V = \frac{nRT}{P}}$  vol of B

- Or - If at STP, can use 22.4 L = 1 mol (at STP)

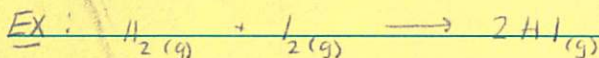
• vol A  $\rightarrow$  mol A  $\rightarrow$  mol B  $\rightarrow$  mass B

$\rightarrow n = \frac{PV}{RT}$  (not at STP)

$\rightarrow 1 \text{ mol} = 22.4 \text{ L (at STP)}$

EX (cont. from above)

$$25.0 \text{ g Zn} \cdot \frac{1 \text{ mol Zn}}{65.4 \text{ g Zn}} \cdot \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}} \cdot \frac{22.4 \text{ L H}_2}{1 \text{ mol H}_2} = \boxed{8.56 \text{ L H}_2}$$



If 5.0 L  $\text{H}_2$  are reacted with excess of  $\text{I}_2$ , what vol. of HI is produced at STP?

[vol A  $\rightarrow$  vol B]

$$5.0 \text{ L H}_2 \cdot \frac{1 \text{ mol H}_2}{22.4 \text{ L H}_2} \cdot \frac{2 \text{ mol HI}}{1 \text{ mol H}_2} \cdot \frac{22.4 \text{ L HI}}{1 \text{ mol HI}} = \boxed{10.0 \text{ L HI}}$$

[Gay Lussac's Law of combining Volumes]

• vol A  $\rightarrow$  vol B --> just multiply by its volume ratios! (at a constant T & P)

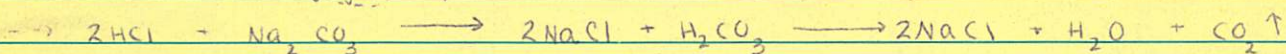
coefficients in  
its respective  
rxns!



05-01-06

EX. If 2.10 g of HCl reacts with 7.34 g of sodium carbonate.

What volume of gas is produced at 730 torr & 18°C?



$$2.10 \text{ g HCl} \cdot \frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}} = 0.0575 \text{ mol HCl have.}$$

$$7.34 \text{ g Na}_2\text{CO}_3 \cdot \frac{1 \text{ mol CO}_2}{106 \text{ g CO}_2} = 0.0692 \text{ mol Na}_2\text{CO}_3 \text{ have}$$

\* water + a  
gas only  
in combustion  
rxns!

$$0.0575 \text{ mol HCl} \cdot \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \text{ mol HCl}} = 0.0288 \text{ mol Na}_2\text{CO}_3 \text{ need} \rightarrow \text{LR: HCl}$$

$$0.0575 \text{ mol HCl} \cdot \frac{1 \text{ mol CO}_2}{2 \text{ mol HCl}} = 0.0288 \text{ mol CO}_2$$

$$V = \frac{nRT}{P} = \frac{(0.0288 \text{ mol})(0.0821 \frac{\text{L atm}}{\text{mol K}})(291 \text{ K})}{(0.961 \text{ atm})} = \boxed{0.716 \text{ L of CO}_2}$$

- to make more tedious  $\rightarrow$  partial pressures (w/ gases being collected over water)



05-03-06

## Graham's Law of Effusion

both deal  
w/ gas  
particles  
moving  
KE

• diffusion - spreading out or mixing of 2 gases in the absence of air currents.

• effusion - gas particles spontaneously passing through an opening or hole in a container.

•  $KE = \frac{1}{2}mv^2$  - comparing 2 particles at same temp. & P

→ same KE

\*  $v =$  velocity

$$KE_1 = KE_2$$

$$\frac{1}{2}m_1v_1^2 = \frac{1}{2}m_2v_2^2$$

$$m_1v_1^2 = m_2v_2^2$$

$$\sqrt{\frac{v_1^2}{v_2^2}} = \sqrt{\frac{m_2}{m_1}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}} \Rightarrow \text{Graham's Law}$$

→ many more variations

$$\frac{v_1}{v_2} = \sqrt{\frac{M_2}{M_1}} = \frac{\text{rate 1}}{\text{rate 2}} = \frac{\text{time 2}}{\text{time 1}} = \frac{\text{distance 1}}{\text{distance 2}} \quad [\text{see book for other variations}]$$

EX compare the rates of diffusion of  $O_2$  &  $H_2$

$$\frac{\text{rate } H_2}{\text{rate } O_2} = \sqrt{\frac{32 \text{ g/mol}}{2 \text{ g/mol}}} = \sqrt{16} = 4X \rightarrow H_2 \text{ diffuses } 4X \text{ faster than } O_2$$

\* diffusion rate